IMPACT OF NATURAL DISASTER RISKS ON JAPANESE SUPPLY CHAINS

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Abstract

This paper discusses different types of major natural disasters risk which occurred in the past that may unexpectedly severely disrupt automakers supply chain networks in Japan in the future. Due to the high risk of natural hazards such as earthquakes or tsunami, it seems that Japan created the best prepared for disruptions industrial supply chain in the world. However the latest climate changes in the environment showed the necessity for improvement their solutions for various types of disasters that occur more frequently.

Keywords: Natural disasters, natural hazards, disaster risks, supply chains, automakers supply chain

1. INTRODUCTION

Japan belongs to the most developed countries in the world despite the fact that it's location as well as natural environment is very complicated. As a result of this, the country is exposed to many natural hazards which may significantly affect continuity in supply chains and can have disruptive effects in automakers industry. Most of the plants and suppliers are located just in the areas that can be prone to disasters, see **Figure1**.

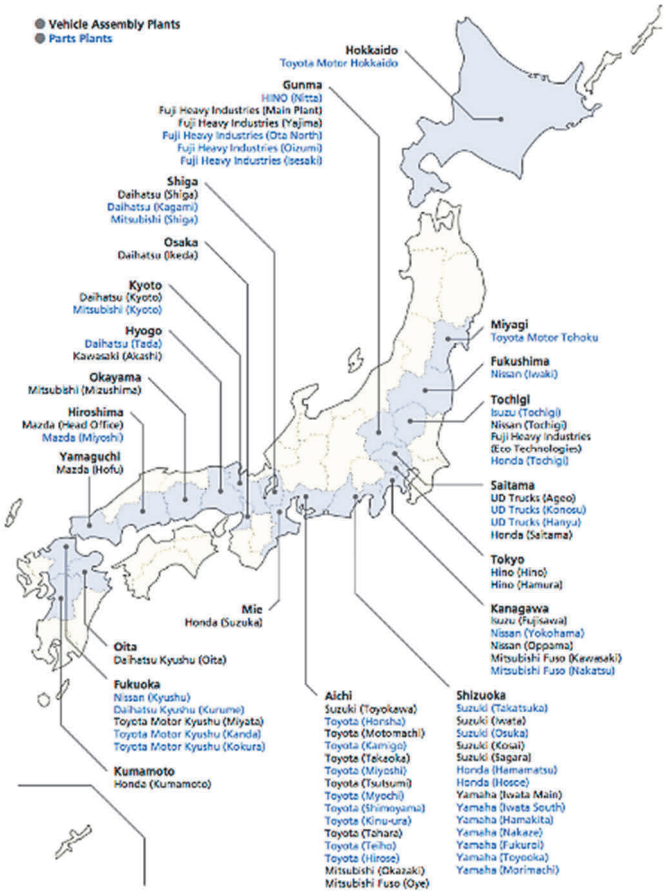

Figure 1 - Automakers and Suppliers in Japan (https://www.thetruthaboutcars.com/2011/03/japan-quake-big-automakers-hit-little-guys-spared-except-subaru/)

2. GEOLOGICAL ENVIRONMENT

Japan sits along the borders of tectonic plates and on their junctions. It is also a part of the Pacific Ring of Fire which surrounds Pacific Ocean. This is belt of very active movements of these plates causing not only earthquakes but also formation of volcanoes and their activity. Almost 10 % of the world's active volcanoes can be found there. And there are also more than 1500 earthquakes yearly. It means that everyday occur some tremors in various part of Japan (https://www.livescience.com/30312-japan-earthquakes-top-10-110408.html). Moreover nearly 80 % of territory is covered with chains of mountains including high amount of faults and volcanic zones (http://www.icil.zarz.agh.edu.pl/images/papers/Marszewska.pdf). The remaining rare plain regions are highly populated.

3. DESCRIPTION OF SELECTED NATURAL DISASTERS - EARTHQUAKES

Due to natural environment it seems that the most common natural disasters in Japan are earthquakes. Much more of the shocks are weak but some of them can be unpredictably dangerous.

Short characteristics of selected natural disasters will show their impact on supply chains disruptions.

3.1. The Great Kantō Earthquake

(1923, September 1) - struck the Kantō Plain in the noon with magnitude 8.2 on the Richter scale. The epicenter was located deep beneath Izu Ōshima Island in Sagami Bay and did huge damage to industry in Kantō Region especially to the old industrial clusters in Tōkyō and Yokohama which burned down in 'fire tornado' spreading following the quake. Tremor also caused devastating *tsunami* up to 12 m which affected coast of Shizuoka Prefecture (https://www.smithsonianmag.com/history/the-great-japan-earthquake-of-1923-1764539/). The earthquake completely devastated two cities and their surroundings. In Yokohama 90 % of factories were completely burnt down [4].

For example, a fire affected the Takuri cars factory which was founded in 1907 in Yokohama. Takuri was the first entirely Japanese-made gasoline engine car (https://carfromjapan.com/article/industry-knowledge/development-history-japanese-automotive-industry/). Another destroyed company was Kaishinsha Motor Car Works in Tōkyō founded in 1911 and producing cars called Datto (later Datsun); (Ibidem). At the beginning of twenties century development of the cars industry was quite impressive with many ambitious goals. Unfortunately, productions were largely stopped by the quake. Factories suffered many losses and supply chains were disturbed after railways tracks between Yokohama and Tōkyō were broken. That is why cars became very important for transportation. In the same year 15,731 vehicles were in use, but one year later the number jumped to 24,333 [7]. The Hakuyosha Ironworks in Tōkyō started to build Ōtomo cars (https://www.toyota-global.com/company/history_of_toyota/75years/text/entering_the_automotive_business/chapter2/section1/item3.html). Two years later former cars dealer Ford Motor Company decided to build an assembly plant in Yokohama because of the main port of Japan and well-developed railway network. Till 1927 permanent large-scale plant was completed [4]. Consequently, production of cars increased in this area and began to spread to other regions [7,8]. Unfortunately, some of Japanese seismologists consider that Tōkyō and Yokohama can be exposed again to mega-quake between 200 to 300 years after the last one [1].

3.2. The Great Hanshin/Kobe Earthquake

(1995, January 17) [6] - belonging to very destructive type called "inland shallow earthquake" occurred in a very early morning hour. The epicenter was located on the small island of Awaji, nearly 20 km from city of Kobe on Honshū Island. City was hit by 7.3 magnitude tremor in Richter scale and it was accompanied by horizontal and vertical movement of 1.2 - 2 m. The six largest container port in the world was completely destroyed. Thousands of buildings collapsed. All water, sewage, gas and power systems were ruptured. Moreover bridges, roads including main coastal highway and railways tracks were devastated. Many factories

and companies were affected and lost their productions. Among them Mitsubishi Motors, Mitsubishi Heavy Industries, Mitsubishi Electric, Kobe Steel, Kawasaki Heavy Industries. Toyota's suppliers were also hit by the quake such as Sumitomo Electric's Itami Works in Itami city producing brake parts, Fujitsu Ten (now Denso Ten)'s Kobe Plant producing car audio and Riken Kobe Institute Center. The shares of automakers fell for Toyota 22 %, Honda 35 % and Nissan 40 % in the first 6 months and needed up to 13 months to recover (https://archive.fortune.com/2011/03/15/autos/autos_japan_earthquake.fortune/index.htm).

A huge devastation in area caused supply chains impossible for comeback in short time. However damaged plants and factories were recovered within a few months. Most of manufacturing capacities had to be transferred to other regions even to reorganized factories specially to support fast recovery. It was predicted that whole recovery for completely destroyed Kobe would take approximately 10 years but in fact it took about 15 months. Just after one-year large part of port was rebuilt. All roads and railways tracks were open again in 5 and 7 months, expressway was rebuilt in 21 months but complete reconstruction was finished after 26 months [3]. This very rapid recovery was possible due to various combinations of activity like transfer of production to other regions, extension of working hours, reduction of cost, etc.

3.3. The Chūetsu Offshore Earthquake

(2007, July 16) - was a strong quake with magnitude 6.6 in Richter scale in the late morning hours. Epicenter was 17 km offshore and 10 km deep in fault between the Amur plate and the Okhotsk plate. The quake was strongly felt in Niigata and other adjacent prefectures up far to Tōkyō.

Capital		¥8,573,597,000 (as of March 2011, all of Riken Corporation)
Number of Employees		1,627 (as of March 2011, all of Riken Corporation)
Major Products		Piston Ring • Engine parts • Approx. 50% of domestic market share Seal Ring • Transmission parts • Approx. 70% of domestic market share
Major Customers	Automobile and other Vehicle Manufacturers	Honda, Suzuki, Toyota, Nissan, Fuji Heavy Industries, Ltd, Mitsubishi, Mazda, Daihatsu, Mitsubishi Fuso Truck and Bus, Nissan Diesel, Hino, Isuzu, Yamaha, Kawasaki Heavy Industries, Ltd, Ford, BMW, VW/Audi, OPEL, FIAT, Renault, Porsche, Jaguar, Hyundai, Kia
	Distributors and Sales Agents for Automobile Parts	Eiwa, Empire, Auto Parts Uematsu, Global Tsusho, Chicago Product, Sumisho Machinery Trade, Daisho Trading, TMT Trading, Toko Trading, Parts International, Heian Boeki, Meiji Sangyo, Motorix International
	Automotive Parts Manufacturers	Aisin AW, Jatco, Musashi Seimitsu Industries, Calsonic Kansei, KYB, Nissin Kogyo, Yamaha Marine, BrotherPrecisionIndustry, Valeo, Aisin Seiki, Waga Precision, ZF

Figure 2 Recovery at Riken's Kashiwazaki Plant (Source: Press Release of Riken and articles of Nihon Keizai Shinbun) [5].

After the quake many leading Japan's automakers factories were forced to stop production as a result of a supply chain interruption. The main supplier Riken Parts Plant located in Kashiwazaki was severely damaged and couldn't deliver key components and have to stop production [3]. Riken is known as the most important supplier of many components such as transmission and engine part like piston rings, gears and others (https://ssc.ca.gov/forms_pubs/cssc_08-02_japanearthquake2007finalv5.pdf), see **Figure 2**. That is why Toyota had to stop production lines at their 12 factories in whole country for at least three days. Nissan Motors and Honda had a similar problem of supply delays from Riken and halted productions at 2 factories. Because of the same problem automaker of Subaru also stopped production. Mitsubishi Motors stopped assembly at 3

plants. And all these automakers lost production of thousands of cars. Riken, the key supplier for all automakers in Japan, holds nearly 50 % of piston rings for automobile engines, 70 % of seal rings in domestic market. That is why Toyota decided to put top priority on restarting Riken production. At first Toyota immediately stopped its operations despite the fact that they had enough piston rings to continue assembly of reduced number of cars. Toyota sent 500 employees and other automakers sent 150 workers to help out. The most important decision concerned resumption of production of Riken at all plants as quick as possible. In such a crisis situation cooperation between automakers and auto parts makers was very important. After nine days following the earthquake Toyota could resume production at 11 of its domestic factories. But vehicles production's recovery of all Japanese automakers took a month [2,5].

3.4. The Great Tōhoku Earthquake

(2011, March 11) - the most powerful in the last 140 years earthquake and biggest in Japan's Recorded History occurred in the middle of the day. Epicenter was located undersea, 130 km offshore. Tremor of 9.1 magnitude in Richter scale and 5000 aftershocks caused a devastating 40 m *tsunami*. The quake was also so strong than shifted Honshū about 2.5 m to the East.Tōhoku Region is a major industry region in the northern part of Japan. Many Toyota's suppliers were seriously affected including small factories of parts for engines as well as Renesas Electronics Corporation (REC) plants, one of the leading semiconductor manufactures in Naka city in Ibaraki Prefecture. In total eight of Renesas's factories were damaged and production of automotive microcontroller was stopped for months. These components are very important because chips are controlling electronic components used in engine and onboard telematics.The situation of Toyota production became very difficult because visibility of supply chain was completely lost. Company spent weeks to identify damages in supplier network and to find a new solution as quick as possible. It concerned the "diamond structure" of a supply chain [2], where multiple suppliers at some tier of the supply chain network were supplied by the same single supplier at a higher tier. Then, the multi sourcing disruption mitigation strategy appeared to be useless. The problem was decentralization of functional components among several suppliers and centralization of simple components in one company with specialized process technology. Another solution to sustain production in critical situation is to be large number of suppliers. Toyota resumed operation in all plants after 38 days later, but whole the recovery took five months [5].

3.5. The Kumamoto Earthquake

(2016, April 16) - occurred in series of powerful tremors. Foreshock hits Mashiki a small city about 12 km from town of Kumamoto being the center for semiconductor fabrication and other manufacturing. And the main shock occurred 28 hours later with 7.0 magnitude in Richter scale. Both these very strong quakes and several hundred others caused great destructions in central Kyūshū such a buildings and bridges collapse, landslides which destroyed villages, roads and bridges. Most of the land transportation became impossible. Toyota Plant located on Kyūshū and other automakers plants such as Nissan and Mitsubishi lost continuity in supply chains and must shutdown their production. Honda car plants in contrast to Honda motorcycle plant have not been affected and production wasn't interrupted. Due to severely damages of the key suppliers Aisin Seiki and Renesas Electronics located exactly in the most affected area, operations in their factories became impossible. Aisin Seiki is the third important supplier of sun roofs, door handles, semiconductors, etc. But Aisin Seiki in Kumamoto is producing the same components like in Aichi, so most of the productions were shifted there. After quake Toyota lost possibility of assembly of 50 000 vehicles and its shares lost 4.8 %, Nissan lost 2.8 % (https://www.manufacturing.net/operations/news/13107168/twin-earthquakes-force-toyota-to-suspend-production-disrupt-manufacturing-across-japan). This time Toyota was better prepared to deal with crisis situation because it learned from the disruptive event of 2011 Tōhoku earthquake. The information networks covering about 4000 auto parts were prepared. This helped to identify affected suppliers and made decision in short time about shifting production of components to alternative suppliers. More companies are recognizing

that they must be prepared to respond quickly to disruptions (https://supplychainmit.com/2018/01/04/3-types-of-risk-that-will-impact-supply-chains-in-2018/).

3.6. The Ōsaka Earthquake

(2018, June 18) - hit Takatsuki, city located about 30 km from Ōsaka. The earthquake measuring 5.6 in Richter scale struck in the morning causing many damages around metropolitan areas of Ōsaka and Kyōto. The quake stopped production lines at several factories including car manufacturers. Toyota Motor Corp., Honda Motor Co. and Mitsubishi Motors located in Kansai Region were forced to suspend production to assess damage at their sites. For that reason, Daihatsu Motors Co (unit of Toyota Motor Corp.) shutdown assembly for one day in Ōsaka, Kyōto and Shiga. Honda Motor Co. and Mitsubishi Motors resumed operations after safety checks.

4. CLIMATIC ENVIRONMENT

Japan is exposed to many severe weather conditions due to its location mostly in the subtropical climate zone and near the edge of Asia Continent. The rainy season occurs regularly at the beginning of summer and last one month during June. Usually several typhoons are passing over Japan between May and October with peak season in September. But the latest climate changes all over the world also affected Japan. The rains became much more intensive and definitely stronger typhoons and tropical storms hit Japan more frequently in unpredictable periods. These intensified, sometimes overlapping phenomena can cause critical situations. The result of these phenomena can be catastrophic floods and landslides. All these circumstances cause various difficulties to choose non-vulnerable locations for manufacturers plants and selection of their suppliers. Thus, the existing industrial supply chain networks in Japan are highly vulnerable to natural disasters that more frequently occur over recent years.

4.1. Rainfall of June and July 2018

(with culmination on July 6) - is called as historic destructive rainfall. It affected mostly western Japan. The heavy rains were caused by a seasonal front and overlapping typhoon Prapiroon (June 28 - July). Massive and devastating floods began in Kyūshū, Shikoku and western part of Honshū. As a result of extremely strong rains landslides and mudslide warnings were issued for Kyūshū, Shikoku and Chūgoku Regions on Honshū Island. The flood had devastating impact on the rail, road networks and power supplies in Chūgoku causing many interruptions of supply chains. Many automakers have suffered. Among them Mazda Motor had to suspend operation for two days at factories located in Fuchū and Hōfu. Daihatsu Motor suspended operation in Nakatsu Plant, Toyota Motor Kyūshū and Toyota Motor halted operation in Miyawaka for a short time (https://asia.nikkei.com/Location/East-Asia/Japan/Intense-rain-in-western-Japan-shuts-down-Daihatsu-and-Mazda-plants). The same situation was in Ōsaka region, where many car factories previously affected by earthquake of June 18 had also to suspend their productions. Mitsubishi, Mazda and Daihatsu factories had to be cleaned after floodwaters and trash. The flood destroyed the national highway, and most of roads remained closed. Many bridges have collapsed and railways were broken. These caused that distribution of components became impossible. Even Mitsubishi in far Kawasaki had to stop assembly for one day because of lack of components. But in the most of factories recovery of production was expected to take only few days (Ibidem).

4.2. The Typhoon Jebi

(2018, September 2-4) hit Shikoku and Kansai region. According to the records, typhoon Jebi was the most powerful storm in last 25 years and made many landfalls and floods. Kansai International Airport was completely shut down. All transportation had to be suspended because of roads and bridges damages. For that reason disruption in supply chains in south-central regions of Japan occurred in a large scale. Automotive corporations located in affected area had to cancel their operations. Among them Toyota Motor suspended

assembly in all its factories and subsidiaries in Aichi region for night, but after accurate assessment of situation resumed operation one day later. Other automakers (Honda, Hino, Daihatsu and Nissan) also halted production for night or 24 hours. The situation in Toyota, Honda and Suzuki factories was quite different and they announced no impact on production. Since most of the companies have prepared their recovery plans mainly in case of earthquake but not for the torrential rains causing floods, their losses were much greater than expected (https://www.automotivelogistics.media/japanese-carmakers-count-the-cost-of-natural-disasters/21499.article).

5. CONCLUSION

Japan is prone to many natural disasters such as volcanic eruptions, earthquakes, soil liquefaction, tsunamis, typhoons, floods, mudflows, landslides, etc. But recently due to the climate changes some weather phenomena appeared with greater intensification. The year 2018 can be a good example for overlapping catastrophic phenomena. Some of them overlapped on other ones caused by earthquakes in the same areas. For instance, Kansai Region had a very bad luck during short period of four months because was prone to the earthquake in June and in the same month to flood after seasonal rains and overlapping typhoon Prapiroon which hit Japan in the first week of July. Unfortunately, the same region was affected by one of the strongest typhoon Jebi in September. That is why 2018 was called as Japan's Year of Catastrophes. Dramatic situation lasted many months showed great needs to rethink occurrence of all possible disasters. Moreover, according to catastrophe risk models created by seismologists it is estimated that great earthquake will return to affected regions in the past [1]. But predictions of mega-quakes are very difficult. And most of Japanese scientists hope that their risk models are in 99 % wrong (https://www.japantimes.co.jp/news/2019/05/20/national/science-health/survey-seismologists-finds-think-99-pacific-mega-quake-predictions-will-likely-prove-wrong/#.XglGv7DQhdg). The lessons learned from these disasters which already had happened gave many important hints what should be considered to be better prepared for the next hazards surely coming in unexpected time, e.g. [9]. Till now Japan has the quickest recovery system, but nevertheless it should be further improved. Disruptions in Japanese supply chain networks that typically operate in 'just-in-time' environment, may cause costly disruptions in manufacturing of finished products.

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